HW3 Solutions

P9.36 (a) The diode is on, $V = 0$ and $I = \frac{10}{3300} = 3.03$ mA.

(b) The diode is off, $I = 0$ and $V = 10$ V.

(c) The diode is on, $V = 0$ and $I = 0$.

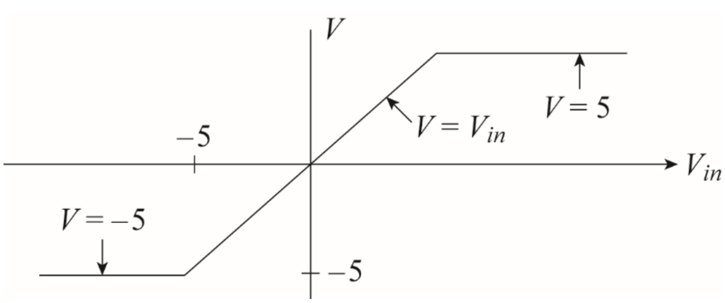
(d) The diode is on, $I = 5$ mA and $V = 5$ V.

P9.38 (a) D_1 is on, D_2 is on, and D_3 is off. $V = 5$ volts and $I = 0$.

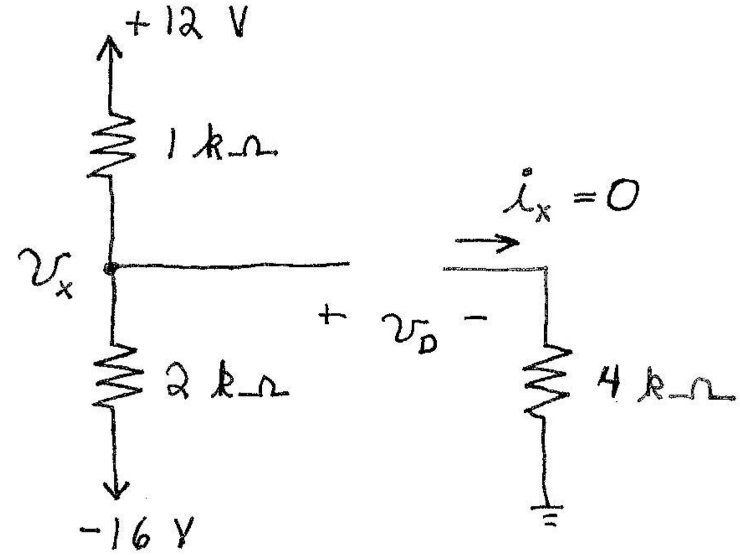
(b)

V_{in}	D_1	D_2	D_3	D_4	V	I
0	on	on	on	on	0	0
2	on	on	on	on	2 V	2 mA
6	off	on	on	off	5 V	5 mA
10	off	on	on	off	5 V	5 mA

The plot of V versus V_{in} is:

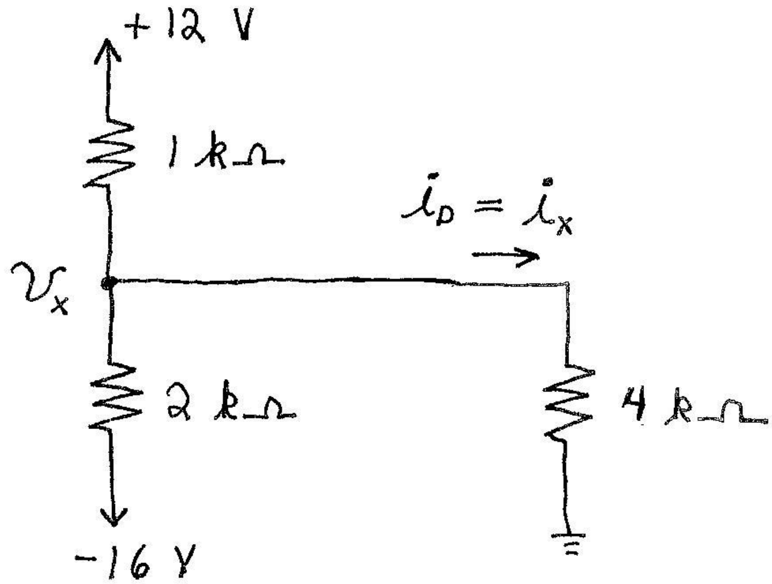


T9.2 If we assume that the diode is off (i.e., an open circuit), the circuit becomes



Writing a KCL equation with resistances in kΩ, currents in mA, and voltages in V, we have $\frac{v_x - 12}{1} + \frac{v_x - (-16)}{2} = 0$. Solving, we find that $v_x = 2.667$ V. However, the voltage across the diode is $v_D = v_x$, which must be negative for the diode to be off. Therefore, the diode must be on.

With the diode assumed to be on (i.e. a short circuit) the circuit becomes



Writing a KCL equation with resistances in kΩ, currents in mA and voltages in V, we have $\frac{v_x - 12}{1} + \frac{v_x - (-16)}{2} + \frac{v_x}{4} = 0$. Solving, we find that $v_x = 2.286$ V. Then, the current through the diode is $i_D = i_x = \frac{v_x}{4} = 0.571$ mA. Of course, a positive value for i_D is consistent with the assumption that the diode is on.

P11.31 Assuming that the MOSFET is in saturation, we have

$$V_{GSQ} = 10 - I_{DQ}$$
$$I_{DQ} = K(V_{GSQ} - V_{to})^2$$

where we have assumed that I_{DQ} and K are in mA and mA/V^2 respectively.

(a) Using the second equation to substitute in the first, substituting values and rearranging, we have

$$V_{GSQ}^2 - 7V_{GSQ} + 6 = 0$$

which yields $V_{GSQ} = 6$ V. (The other root, $V_{GSQ} = 1$ V, is extraneous.)

$$I_{DQ} = 4 \text{ mA}$$

$$V_{DSQ} = 20 - 2I_{DQ} = 12 \text{ V}$$

(b) Similarly for the second set of values, we have

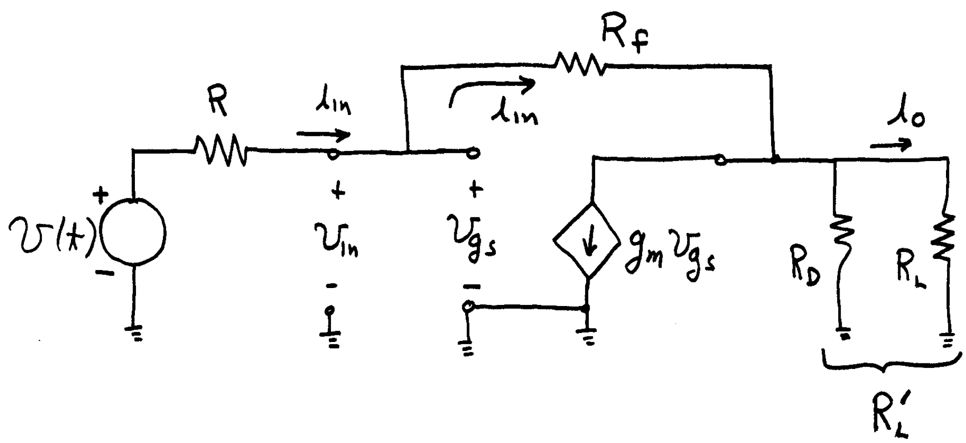
$$V_{GSQ}^2 - 3.5V_{GSQ} - 1 = 0$$

$$V_{GSQ} = 3.765 \text{ V}$$

$$I_{DQ} = 6.234 \text{ mA}$$

$$V_{DSQ} = 20 - 2I_{DQ} = 7.53 \text{ V}$$

P11.52 (a)

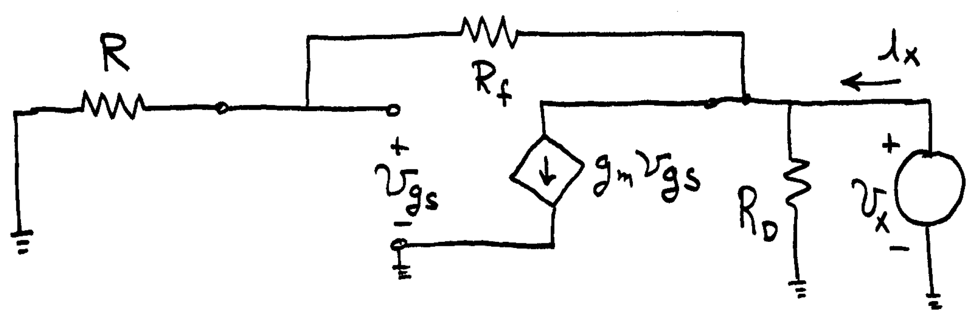


(b) $v_o = R_L'(i_{in} - g_m v_{in})$ $\qquad i_{in} = (v_{in} - v_o)/R_f$

$$A_v = \frac{v_o}{v_{in}} = \frac{R_L' - g_m R_L' R_f}{R_L' + R_f}$$

$$R_{in} = \frac{v_{in}}{i_{in}} = \frac{R_f}{1 - A_v}$$

The circuit used to determine output impedance is:

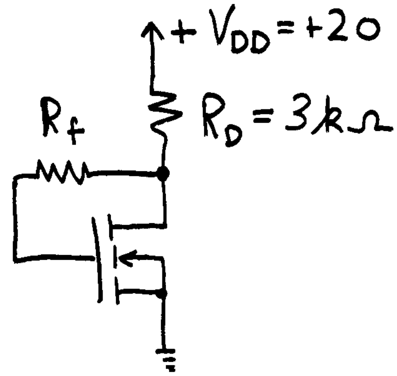


We define $R_D' = R_D \| (R + R_f)$. Then we can write

$$v_{gs} = v_x \frac{R}{R + R_f} \quad \text{and} \quad i_x = \frac{v_x}{R_D'} + g_m v_{gs}$$

$$R_o = \frac{v_x}{i_x} = \frac{1}{\dfrac{1}{R_D'} + \dfrac{g_m R}{R_f + R}}$$

(c) The dc circuit is:



$V_{GSQ} = V_{DSQ}$ $\quad I_{DQ} = K(V_{DSQ} - V_{to})^2$ $\quad I_{DQ} = (V_{DD} - V_{DSQ})/R_D$

Using the above equations, we obtain

$$3V_{DSQ}^2 - 29V_{DSQ} + 55 = 0$$

$V_{DSQ} = 7.08$ V and $I_{DQ} = 4.31$ mA

$$g_m = \left.\frac{\partial i_D}{\partial v_{GS}}\right|_{Q-\text{point}} = 2K\left(V_{GSQ} - V_{to}\right) = 4.16 \times 10^{-3} \text{ S}$$

(d) $R_L' = R_D \| R_L = 2.31\,\text{k}\Omega$

$A_v = -9.37$

$R_{in} = 9.64\ \text{k}\Omega$

$R_o = 414\ \Omega$

(e) $v_o(t) = v(t) \times \dfrac{R_{in}}{R + R_{in}} \times A_v = -0.164\sin(2000\pi t)$

(f) This is an inverting amplifier that has a very low input impedance compared to many other FET amplifiers.

P11.13 (a) This is an NMOS transistor. We have $v_{GS} = V_{in}$ and $v_{DS} = 5$ V. With $V_{in} = 0$, the transistor operates in cutoff and $I_a = i_D = 0$. With $V_{in} = 5$, the transistor operates in satruation and $I_a = i_D = K(v_{GS} - V_{to})^2 = 3.2$ mA.

(b) This is a PMOS transistor. We have $v_{GS} = V_{in} - 5$ and $v_{DS} = -5$ V. With $V_{in} = 0$, the transistor operates in satruation and $I_b = i_D = K(v_{GS} - V_{to})^2 = 3.2$ mA. With $V_{in} = 5$, the transistor operates in cutoff and $I_b = i_D = 0$.